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tical reports published justify the belief that when the treatment is instituted at an early date after the bite, and is properly carried out, its protective value is almost absolute. At the Pasteur Institute in Paris 9,433 persons were treated during the years 1886 to 1890, inclusive. The total mortality from hydrophobia among those treated was considerably less than one per cent. (0.61). In 1890 416 persons were treated who had been bitten by animals proved to be rabid, and among these there was not a single death. In 1891 the number of inoculations was 1,539, with a mortality of 0.25%; in 1892, 1,790 with a mortality of 0.22%; in 1893, 1,648 with a mortality of 0.36%; in 1894, 1,387 with a mortality of 0.50%.

There has been and is still a considerable amount of scepticism among members of the medical profession, and others, as to the practical value of Pasteur's inoculations for the prevention of hydrophobia; and some physicians have even contended that the disease known by this name is not the result of infection from the bite of a rabid animal, but is a nervous affection due to fear. The time at my disposal will not permit me to present for your consideration the experimental and clinical evidence upon which I base the assertion that nothing in the domain of science is more thoroughly demonstrated than the fact that there is a specific infectious disease known to us as rabies, or hydrophobia, which may be communicated to man, or from one animal to another, by the bite of a rabid animal; and that Pasteur's inoculations prevent the development of the disease in animals which have been infected by the bite of a rabid animal or by inoculations with infectious material from the central nervous system. This being the case, it is evident that there is a scientific basis for Pasteur's method of prophylaxis as applied to man, and his published statistics give ample evidence of the success of the method as carried out at

the Pasteur Institute in Paris and elsewhere. Great as have been the practical results which have already followed Pasteur's brilliant discoveries, there is reason to believe that in the future still more will be accomplished, especially in combatting the infectious diseases of man. Having pointed out the way, a multitude of earnest investigators in various parts of the world are now engaged in laboratory researches relating to the cause, prevention and cure of infectious diseases. Already, in the treatment of diphtheria and of tetanus with blood serum obtained from immune animals, results have been obtained of the highest importance, and it seems probable that in the near future other infectious diseases will be cured by a specific treatment based upon scientific information obtained by those who have been following in the pathway marked out by Pasteur, the illustrious pioneer in this line of research.

GEO. M. STERNBERG.

HELMHOLTZ.

HERMANN LUDWIG FERDINAND, BARON VON HELMHOLTZ, was born at Potsdam on August 31, 1821.

In 1842 he received his decree in medicine at Berlin, and entered the government service as an army surgeon.

In 1847 he published his essay on the Conservation of Energy.

In 1849 he was appointed professor of physiology at Bonn.

In 1851 he invented the Ophthalmoscope.

In 1855 he was made professor of anatomy and physiology at Bonn.

In 1859 he was appointed to the same chair at Heidelberg.

In 1860 he was made one of the foreign members of the Royal Society of London.

In 1863 he published his great work on the 'Sensations of Tone.'

In 1866 the first edition of his 'Physiological Optics' was completed.

In 1871 he was made professor of natural philosophy at the University of Berlin.

In 1873 he received from the Royal Society the highest distinction which it can bestow, the Copley Medal; and in the same year the King of Prussia conferred upon him the Order of Merit in Science and Art.

In 1883 hereditary nobility was conferred upon him by Emperor William I.

In 1887 he assumed the directorship of the great Physico-technical Institute, founded by the German government at Charlottenberg.

In 1891 the seventieth anniversary of his birth was celebrated with great ceremony and he was placed at the head of the civil list by the German Emperor.

In 1893 he visited America, serving as President of the International Electrical Congress held in Chicago.

In 1894, on September 8th, he died at the age of seventy-three years.

Such is the brief outline of the life of one of the most extraordinary men of the present century. To perfect such a sketch in anything like just proportions, or to attempt in the few minutes allotted to me to-night to set forth anything like a fair estimate of the labors of one of whom it may be justly said that he was the most accomplished scholar of modern times, is a task no one would seek. Nor can one easily decline the honor which is carried by an invitation from a commission representing the scientific societies of Washington to take part in so memorable a commemoration as this. Under the circumstances, I must confine myself to an exposition, all too brief, of a few only of the principal contributions to human knowledge among the great number for which the world is indebted to Prof. Helmholtz. It was his distinctive characteristic that among the exponents of modern science he stood quite alone in being really great along several lines. He was in the be-

ginning and always a pure mathematician of high type. Anatomists and physiologists claimed him for their own. During a few days' stay in New York in 1893, after having presided over the International Congress of Electricians, he was entertained by a distinguished surgeon, the leading eye specialist of the country, and ophthalmologists flocked to do him honor as one of the founders of their profession. When, in 1881, he gave the Faraday lecture before the Chemical Society of London, the President of Society in presenting to him the Faraday Metal, declared that eminent as was Helmholtz as an anatomist, a physiologist, a physicist and a mathematician, he was distinctly claimed by the chemists. Nor were these only idle compliments. Only a few days ago I happened on a most curious and interesting illustration of the unequalled extent of his scientific constituency in finding, in a widely known journal published in London, his obituary notice indexed under the heading, 'The Stage and Music,' where his name appeared accompanied by only that of Anton Rubenstein. His great work on the 'Sensations of Tone' and his analysis of the vowel sounds of the human voice gave him a lasting fame among musicians.

Psychology as well as *Æsthetics* was benefitted by his touch, but I think it will be generally admitted that he was first of all, and more than all else, a physicist. Indeed it may be said that the best fruits of his study of other branches of science grew out of the skill with which he engrafted upon them the methods of investigation for which we are primarily indebted to the physicist.

When a boy he had acquired a fondness for the study of Nature. His father was a professor of literature in the gymnasium at Potsdam; his mother a woman of English descent. Although he was encouraged in the development of his youthful tastes as much as possible, the necessity for earning

a living directed his professional studies towards medicine and he became a military surgeon. As a physiologist he was led to the study of 'vital force'; his taste for mathematics and physics forced him to the dynamical point of view, and his first great paper, prepared before he was twenty-six years of age, was on the Conservation of Energy. It is now nearly fifty years since this essay was presented to the Physical Society of Berlin, and doubtless quite fifty years since it was actually worked out. Its excellence is shown by the fact that if rewritten to-day it would be changed only a little in its nomenclature. Fifty years ago the great law of the Conservation of Energy, which will ever be regarded as the most pregnant and far-reaching generalization of this century, was so far from being known or recognized that many of the ablest men of the time either regarded it as a 'fanciful speculation'—or did not regard it at all.

As a matter of ordinary mechanics, it had long been admitted that no machine could create power and, as a part of that applied was always lost or frittered away in friction, the work coming out of a machine must always be less than that put into it. The first great advance had been made by an American, Benjamin Thompson, afterwards Count Rumford, when he asked what became of that part lost in friction and found his answer in the heat generated thereby, thus proving that 'heat was a mode of motion,' 'rather than an imponderable agent,' as it was rather ambiguously designated up to nearly the middle of this century, but that *all* of the forces of nature were so related to each other as to be interconvertible and that the sum total of all the energies of the universe was always the same, energy being no more capable of creation or destruction than matter; these were great facts, mere glimpses of which had been permitted to the physicists of the early part of

the century. Helmholtz was certainly one of the first to completely grasp this splendid generalization, and not more than two or three others stand with him in the credit which is due for its complete proof and general acceptance. His first contribution had the merit of being quite original in conception and execution, for he then knew almost nothing of what others had done; he was entirely ignorant of the important paper of his fellow countryman, Mayer, and knew only a little of Joule's earlier work. The principle of the conservation of energy, which for a quarter of a century has been the open-sesame to every important advance in physical science, was not then, to say the least, a popular topic. But for five or six years a young Englishman named Joule, not yet thirty years old, had been engaged with it and, from the point of view of the engineer, had made it his own. On the 28th of April, 1847, he gave a popular lecture in Manchester, where he lived and died, which was the first full exposition of the theory. A few weeks later Helmholtz read his paper in Berlin. In England even the local press refused to publish Joule's address, but finally the *Manchester Courier*, moved by the family influence (the elder Joule being a wealthy brewer), promised to insert the whole, as a special favor. In Germany the subject met with only a little more favorable reception, and the leading scientific journal, *Poggendorff's Annalen*, declined to publish Helmholtz's paper. Even at the meeting of the British Association at Oxford a few months after the Manchester address, when Joule again undertook the exposition of his theory and his experimental proofs of it, before what ought to have been a more friendly audience, he was advised by the Chairman to be brief, and no discussion of his paper was invited. As Joule himself relates, his presentation of the subject would have again proved a failure, 'if a young man had not risen in

the section and by his intelligent observations created a lively interest in the new theory.' This young man was William Thomson, then twenty-three years old; now, Lord Kelvin, the foremost of living physicists.

The tremendous blows struck by Helmholtz in support of the new doctrine, from that time until it was no longer in the balance give evidence alike of his extraordinary talents and his fine courage. The publication of this important essay in 1847 had also the effect of bringing about an immediate appreciation of his abilities. Du Bois-Reymond gave a copy of it to Tyndall, then a student of Magnus in Berlin, saying that it was the product of the first head in Europe. He was shortly removed to the more favorable environment of a University professorship at Königsburg. During the next twenty years he advanced from Königsburg to Bonn, from Bonn to Heidelberg and from Heidelberg to Berlin. While it was only on reaching the University of Berlin that he assumed his true function of Professor of Physics, yet the previous two decades had been rich in the application of physical methods to physiological subjects.

In 1863 He published the remarkable monograph on the 'Sensations of Tone.' This work is a most masterly analysis of the whole subject implied in its title and must always remain a classic. Only one or two of the most important results of the profound researches of the author can be referred to here. As every one knows, the character of a musical tone is threefold. There is first its pitch, which has long been known to depend upon the frequency of vibration of the string or reed, or whatever gives rise to the sound; there is next the loudness, which depends upon the amplitude of this variation, or, in a general way, on the energy expended by the vibrating body. But two tones may agree in pitch and in loudness and still produce very different

impressions on the ear. It is this which makes it possible to know when a musical tone is heard that it comes from an organ, or a flute, or the human voice. It enables an expert to know on hearing a single note from a violin that the instrument was made in a given year by a certain artist; by virtue of this characteristic one instantly recognizes a voice which one has not heard for many years as belonging to a particular individual. So little was known of the physical cause of this inherent peculiarity of a sound that for many years it went unnamed. Helmholtz called it the 'Klangfarbe' literally, 'tone-color;' but in English the term 'quality' is now universally applied to it. What is the physical cause of the quality of a tone? is the question, the answer to which he sought. All that there is in a tone, he said, pitch, intensity and quality, must be borne upon the air-waves by which the sound is communicated to the ear, and all that these waves bear must be impressed upon them by the vibrating body in which the sound originates. He did not fail to recognize, however, and this was extremely important, that there might exist peculiarities in the receiving instrument, the ear (through the operation of whose mechanism the motion of matter is interpreted as a sensation), the existence of which would materially modify the final outcome, to the end that two physically identical tones might give rise, under certain circumstances, to different sensations. Guided by these principles he discovered that the quality of a tone, that characteristic which gives charm to it, was really due to its impurity; that if two perfectly pure tones, generated by simple, pendular vibrations, agreed in pitch and loudness it would be quite impossible to distinguish them. But, practically, such tones are never produced; all ordinary tones are composite, made up of the fundamental, which generally fixes the nominal pitch

of the whole, and a series, more or less complete and extended, of overtures or harmonics, the vibration frequencies of which are two, three, four or some other multiple of that of the fundamental. Without these, the fundamental, though pure, was plain, dull and insipid; with them it formed a composite with quality, soft it may be, or brilliant or rich or harsh, or any of the thousand things which may be said of a tone. *Which* it was and *what* it was, was determined by the relative proportions of the several overtones, indefinite in number, in the composite whole. This beautiful hypothesis was illustrated and established by innumerable experiments, and it was proved that the *form of the air wave* was the quality of the tone, and that this form originated in the mode of vibration of the sounding body, which was almost universally not simple, but complex. But the most important work of Helmholtz along this line was the extension of this theory to the solution of a problem more than two thousand years old, proposed, in fact, by the Greek, Pythagoras. It meant nothing less than the physical explanation of harmony. Why are certain combinations of musical tones agreeable and others unpleasant?—and, indeed, the answer to this tells as well, why a certain *succession* of tones, as in a musical scale, is likely to be generally acceptable to the human ear. Lack of time will only permit me to say that in the interference and consequent *beating* of certain of the overtones or upper partials, of two fundamentals, Helmholtz found the explanation of their dissonance, and that while in certain particulars his theory as originally published has been criticised, it is in general universally accepted and admitted to be one of the most splendid contributions to modern science.

I am warned, also, that I must not speak of that other great work, the Physiological Optics, as I would so gladly do if time per-

mitted. Helmholtz was actually engaged in the preparation of this and the 'Sensations of Tone' during the same years. No other man in the world could have written these, for no other was at once an accomplished physiologist, mathematician and physicist. While I cannot speak of his contributions to the science of optics and ophthalmology, I must not omit brief reference to his invention of the ophthalmoscope and the ophthalmometer. Anxious to actually see what goes on in the eye, and especially on the retina, that wonderful screen on which the image of the visible world is focussed, he invented the ophthalmoscope. The qualitative victory was followed by the quantitative, in the invention of the ophthalmometer, by means of which accurate measurements of the various curved surfaces in the eye could be made. These two instruments have been to ophthalmic surgery what the telescope and graduated circle have been to astronomy. So exact has the science of the eye become through their use that it is not great exaggeration to say that one may now have a disordered eye repaired, corrected and set going with little more uncertainty than attends the performance of the same duty for an ill-conditioned chronometer. Had Helmholtz accomplished nothing except the invention of these instruments he would have been entitled to the thanks of all mankind, on account of the comfort they have added to life and the pain and suffering they have prevented.

If I had devoted all of the time allotted to me to a simple enumeration of the contributions to human knowledge made by von Helmholtz during fifty years of marvellous intellectual activity I must have left my task incomplete, but I must not close without reference to one or two of these, more purely physical in their character and equally stamped with the genius of their author.

Perhaps Nature has shown herself most reticent and unyielding when scientific men have questioned her as to the ultimate structure of matter, the full knowledge of which includes a satisfactory explanation of the force of gravity which is one of its essential properties. Hypotheses which have been very useful in their time have been finally rejected because they involved some impossible conception, such as action at a distance, which was for a long time believed possible. The tendency is now and has long been to regard space, or at least that part of it in which we have any particular interest, as a plenum and to assume a continuous, incompressible, frictionless elastic fluid in which and of which all things are. In the development of his exquisite theory of vortex motion, Helmholtz demonstrated the possibility of a portion of such a fluid being differentiated from the rest in virtue of a peculiar motion impressed upon it, and that when so differentiated it must forever remain so, a fact which was quickly seized upon by Lord Kelvin as the foundation of a vortex theory of matter, thus sharing with Helmholtz the honor of having approached nearer than all others to the solution of the great mystery.

From the genesis of an atom to the origin of the universe seems a long step, but it is not too great for the intellect of man. The well-known Nebular Hypothesis was advanced long before Helmholtz's time, but a better knowledge of Thermodynamics had quite upset one of its generally accepted principles, namely, that the original nebulous matter was fiery hot. As long ago as 1854 Helmholtz showed that this was not a necessary assumption and proved that mutual gravitation between the parts of the sun might have generated the heat to which its present high temperature is due. The greatest philosophers of the past hundred years have attempted to account for this high temperature and for its maintenance,

on which all life on this globe depends. The simple dynamical theory of Helmholtz has survived all others and is to-day universally accepted.

But I must cut short this absolutely inadequate account of what the scholar did, that I may say a word or two of what the man was. Although one of the most modest and quiet of men, no one could meet him without feeling the charm of his personality. Although he bore a dignity which became the great master of science which he was everywhere admitted to be, he was approachable in an extraordinary degree. He was eloquent in popular address and believed in the obligations of men of science to the general public. In scientific discussion, whether on his feet or with pen in hand, there was a certain massiveness about his style and manner which was generally irresistible. In his attacks upon the region of the unknown he showed possibly less brilliant strategy than one or two of his contemporaries, but he rarely, if ever, found himself obliged to conduct a retreat. In 1893 he was selected by the Emperor as the head of the German delegation, five in number, to the International Electrical Congress held in Chicago in August of that year. His more than three score and ten years weighed upon him, and he begged to be relieved of the duty. The young Kaiser, who was fond of him and who loved to honor him in every way, sent for him. On hearing his modest plea he said, "Helmholtz, you must go; I want the Americans to see the best I have of every kind, and you are our greatest and best man." As becomes a dutiful subject he yielded. While in this country every honor was shown him. Here he found many of the hundreds or thousands of his pupils who everywhere in the world are adding lustre to his name by perpetuating his spirit and his methods, and all were ready to serve him. Electrician, mathematician, physiologist and physicist,

he found everywhere a large and appreciative constituency, while his own almost boyish pleasure in whatever he saw that was novel was charming to see. On his homeward voyage he met with an accident which was thought by many to be the beginning of the end. Up to the time of his death, which occurred about a year later, he continued, but not very actively, to direct the great institution for original research, in which, by the wisdom of an appreciative government, he had found full scope for his powers. His interest in the important work done at the Chicago Congress continued through this year, and one of the few long letters he wrote had reference to its proceedings. On the 8th of September, 1894, he died, and on the 13th he was buried at Charlottenberg, princes and peasants alike mourning his loss.

Von Helmholtz occupied so large a part of the scientific horizon and for so long a time that we have not yet become accustomed to his absence. But it is not too soon to agree that the following admirable lines which appeared in the *London Punch* a little more than a year ago express in some measure our judgment of the man and his work:

"What matter titles? *Helmholtz* is a name
That challenges alone the award of fame!
When Emperors, Kings, Pretenders, shadows all,
Leave not a dust-trace on our whirling ball,
Thy work, oh grave-eyed searcher, shall endure,
Unmarred by faction, from low passion pure."

T. C. MENDENHALL.

CURRENT NOTES ON PHYSIOGRAPHY.

THE TEMPERATURE OF LAKES.

A CAREFUL study of the temperature of lakes, leading to important economic results in connection with water supply, has lately been completed by Desmond Fitzgerald, of the Boston Water Works (Trans. Amer. Soc. Civil Engineers, xxxiv, 1895, 67-109). Many of the observations have been taken

with the thermophone (see Amer. Meteorol. Journ., xii, 1895, 35-50), thus gaining much accuracy and saving much time. It appears from the numerous diagrams and tables in the essay, as well as from the text, that small water bodies, such as Lake Cochituate, one of the chief supplies for Boston, are generally in stable equilibrium. During the winter, when small lakes are frozen, the surface water to a depth of about ten feet is colder and lighter than the great body of deeper water whose temperature is that of maximum density. All through the summer, stability and stagnation again prevail, the surface water to a depth of thirty or forty feet being then warmer and lighter than the bottom water, which remains between 40° and 45°. During this summer period of stagnation, and after the oxygen dissolved in the water has been used in the decomposition of sinking organic substances, they accumulate for the remainder of the season; the water then becomes darker and darker, until by October it is very yellow and generally of a disagreeable smell. But in April, and again in November, the temperature of the lake is essentially constant from top to bottom; the water body is then in indifferent equilibrium and is easily overturned by the wind. In November particularly this overturning brings all the impure bottom water to the surface; infusoria and diatoms begin to grow in enormous numbers, because of the supply of food thus provided. While the degree of impurity of the stagnant bottom water varies in different lakes, it may in some become a serious annoyance; and it is suggested that, where possible, the bottom water should there be drawn off from reservoirs and 'wasted' before the November overturning arrives.

WINDS INJURIOUS TO VEGETATION AND CROPS.

UNDER the above title, the late Prof. Geo. E. Curtis contributed to the International